

STAMPER, LITHOGRAPHIC METHOD OF USING THE STAMPER  
AND METHOD OF FORMING A STRUCTURE  
BY A LITHOGRAPHIC PATTERN

## BACKGROUND OF THE INVENTION

### Field of the Invention

The present invention relates to a stamper, a lithographic method using the stamper and a method of  
5 forming a structure by a lithographic pattern.

### Description of the Related Art

In the conventional process for fabricating a semiconductor device, the photolithography has often been used as a technique for pattern transfer to form a  
10 finely detailed structure. With the miniaturization of the pattern, however, the pattern size is limited by the wavelength of the light used for exposure on the one hand and a mechanism is required for controlling the mask position with high accuracy on the other hand,  
15 thereby leading to the disadvantage of a high apparatus cost. A technique for forming a fine pattern at a low cost has been disclosed in U.S. Patent No. 5,772,905. According to this technique, a stepped stamper having the same protrusions and recesses as the desired  
20 pattern to be formed on the substrate is pressed on a resist film layer formed on the surface of an object substrate thereby to transfer a predetermined pattern. This nano imprint technique described in U.S. Patent No. 5,772,905 cited above is considered to make it

possible to form a pattern as small as not more than 25 nanometers.

Even with the imprint technique considered to be capable of forming a fine pattern, however, a  
5 plurality of stamps of patterns are required to be prepared, as in photolithography, to form a structure configured of a plurality of patterns. Also, the positions of patterns are required to be matched with each other, thereby increasing the fabrication cost  
10 unavoidably.

#### SUMMARY OF THE INVENTION

In view of the technical problems described above, the object of the present invention is to provide a stamper for transferring a plurality of  
15 patterns collectively.

This object can be achieved by a stamper for transferring a plurality of patterns collectively, comprising a substrate and a plurality of protrusions having different heights formed on one of the surfaces  
20 of the substrate, wherein the protrusions of larger height have a stack structure including at least two layers of not less than two types of materials.

The protrusions of smaller height preferably have a stack structure with a smaller number of layers  
25 than the protrusions of larger height.

Also, the adjoining ones of the materials of the protrusions of larger height preferably have

different etching rates for a predetermined etching technique.

Further, the areas of the materials of the protrusions having the same height from the substrate surface are preferably formed of the same type of material.

Other objects, features and advantages of the invention will become apparent from the following description of the embodiments of the invention taken in conjunction with the accompanying drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a perspective view of a stamper structure according to the invention.

Figs. 2A to 2H are diagrams for explaining a process of steps for fabricating a stamper according to the invention.

Figs. 3A to 3D are diagrams for explaining another process of the steps for fabricating a stamper according to the invention.

Figs. 4A to 4F are diagrams for explaining still another process of the steps for fabricating a stamper according to the invention.

Fig. 5 is a diagram for explaining a defect occurring at the time of pattern transfer.

Figs. 6A to 6C are diagrams for explaining a pattern transfer method according to the invention.

Figs. 7A to 7E are diagrams for explaining a

pattern transfer method according to the invention.

Figs. 8A to 8E are diagrams for explaining the process of steps for forming a stepped channel or groove according to the invention.

5 Figs. 9A to 9H are diagrams for explaining the process of steps for forming a structure according to the invention.

Figs. 10A to 10L are diagrams for explaining the process of steps for forming a multilayer wiring  
10 according to the invention.

#### DESCRIPTION OF THE EMBODIMENTS

##### (Embodiment 1)

An embodiment of the invention will be explained below. The explanation of this embodiment  
15 deals with the structure and a method of fabricating a stamper.

Fig. 1 is a perspective view of a stamper according to the invention. A stamper 101 has a structure formed with protrusions 105, 106, 107, 108 of  
20 different shapes on one of the surfaces of a stamper substrate 102. The protrusions 105 and 106 both have a simple shape of different heights. The lower protrusion 105 is composed of a first material alone, while the portion of the taller protrusion 106 having the  
25 same height as the protrusion 105 is composed of the first material 103 while the portion of the taller protrusion 106 taller than the protrusion 105 is

composed of a second material 104. The protrusions 107, 108 are both formed of portions having different heights combined. Like in the protrusion 106, the portion of each of the protrusions 107, 108 having the same height as the protrusion 105 is composed of the first material 103 while the portion thereof taller than the protrusion 105 is composed of the second material 104. One of the features of this embodiment lies in that the stamper comprises a substrate and a plurality of members (protrusion 106) of a stack structure having a plurality of steps formed on the substrate, each of the members being composed of at least two types of different materials. Also, the adjoining ones of the layers of each member are formed of materials having different etching rates against a predetermined etching method.

In the case where a silicon substrate is used as a stamper material, the photolithography and the etching technique generally used in the semiconductor fabrication process are applicable in producing an irregular shape.

Figs. 2A to 2H are diagrams for explaining the process of fabricating a stamper. First, as shown in Fig. 2A, a silicon oxide film 202 having a thickness of 1.5 micrometers is formed on one surface of a single-crystal silicon substrate 201 having a thickness of 500 micrometers. Further, a silicon film 203 having a thickness of 1.0 micrometer is formed over the entire

surface of the silicon oxide film 202.

Next, as shown in Fig. 2B, the surface of the polycrystal silicon film 203 is coated with an ultraviolet-softened resist 204.

5           As the next step, as shown in Fig. 2C, the ultraviolet light is radiated on the resist 204 by an ultraviolet lamp 206 through a photomask 205 having a predetermined pattern, so that the resist is softened at the radiated positions thereby to form softened-  
10 resist portions 207.

The resist 204 is developed and the softened resist portions 207 are removed. Thus, as shown in Fig. 2D, exposed areas 208 are formed on the surface of the silicon film 203. The width of each exposed area  
15 208 is 3.0 micrometers.

Next, the exposed areas 208 of the polycrystal silicon film 203 is dry-etched with  $\text{Cl}_2$  (chlorine) gas. Only the polycrystal silicon film 203 is selectively etched, and the underlying silicon oxide  
20 film 202 is not substantially etched. As a result, a structure shown in Fig. 2E is produced.

The remaining resist 204 is removed in its entirety, and another resist 204 is coated on the surface of the polycrystal silicon films 203 and the  
25 silicon oxide film 202 for exposure and development with a photomask (not shown) having a second pattern. In this way, a structure with the silicon oxide film 202 exposed in the exposed areas 208 is obtained as

shown in Fig. 2F. The width of each exposed area 208 is 1.0 micrometer.

The exposed areas 208 are dry-etched with the  $\text{CHF}_3/\text{O}_2$  gas. Only the silicon oxide film 202 is  
5 selectively etched, while the underlying single-crystal silicon substrate 201 is not substantially etched. Thus, a structure shown in Fig. 2G is obtained.

The remaining part of the resist 204 is removed entirely. A stamper 101 having a structure  
10 shown in Fig. 2H is produced.

This embodiment represents a case in which the  $\text{Cl}_2$  gas is used as an etching gas for the polycrystal silicon film 203. Nevertheless, such a gas as  $\text{CF}_4/\text{O}_2$ ,  $\text{HBr}$  or  $\text{Cl}_2/\text{HBr}/\text{O}_2$  can alternatively be used  
15 with equal effect. These gases, like the  $\text{Cl}_2$  gas, have a much lower etching rate against the silicon oxide film than against the polycrystal silicon film. Thus, the polycrystal silicon film alone can be selectively etched. Also, as an alternative to the  $\text{CHF}_3/\text{O}_2$  gas  
20 described above as an etching gas for the silicon oxide film 202, any of such gases as  $\text{CF}_4/\text{H}_2$ ,  $\text{CHF}/\text{O}_2$ ,  $\text{C}_2\text{F}_6$  and  $\text{C}_3\text{F}_8$  can alternatively be used with equal effect. These gases, like the  $\text{CHF}_3/\text{O}_2$  gas, have a much lower etching rate against the polycrystal silicon film than against  
25 the silicon oxide film, and therefore only the silicon oxide film can be selectively etched.

As in this embodiment, the use of an etching process capable of exhibiting selectivity between the



adjoining materials of protrusions having a stack structure makes it possible to control the height of each step according to the thickness of each material. In other words, by regulating the thickness of each material uniformly, the dimensions can be controlled in stable fashion without regard to any variations of the etching conditions.

(Embodiment 2)

Another embodiment of the invention will be explained below. This embodiment refers to a structure of a stamper and a method of fabricating the stamper.

The stamper described in the first embodiment can of course be used for pattern transfer. After repeated transfer operations, however, a pattern transfer failure may be caused by the degeneration of the stamper. For this reason, the cost may sometimes be effectively reduced by using, as a new stamper, the structure obtained by duplicating a pattern of the first stamper making up the original plate.

Figs. 3A to 3D show a method of fabricating a stamper using, as an original plate, the stamper obtained according to the first embodiment. First, as shown in Fig. 3A, the entire surface of the stamper 101 having a stepped pattern is formed with a metal nickel film 301 by sputtering. Next, as shown in Fig 3B, the surface of the metal nickel film 301 is electroplated thereby to form a nickel plated film 302. Next, as shown in Fig. 3C, the stamper plate 101 is separated

from the nickel plated film 302. In this way, a  
stamper 303 having a nickel plated layer can be pro-  
duced as shown in Fig. 3D. This method can reproduce  
the stamper 303 having protrusions of a stepped pattern  
5 reverse to that of the stamper 101 making up the  
original plate.

Figs. 4A to 4F show another method of  
fabricating a stamper using, as an original plate, the  
stamper produced according to the first embodiment.  
10 First, the stamper 101 making up the original plate in  
contact with an epoxy resin substrate 401 is heated to  
about the glass transition temperature of the epoxy  
resin substrate 401 thereby to soften the substrate.  
In this way, the epoxy resin substrate 401 is deformed  
15 as shown in Fig. 4A. The whole assembly is then cooled  
to 25°C, after which the stamper 101 and the epoxy  
resin substrate 401 are separated from each other as  
shown in Fig. 4B. Next, the surface of the epoxy resin  
substrate 401 having a stepped pattern is formed with a  
20 nickel metal film 402 by sputtering thereby to produce  
the structure shown in Fig. 4C. As shown in Fig. 4D,  
the surface of the nickel metal film 402 is formed with  
a nickel plated film 403 by electroplating. As shown  
in Fig. 4E, the nickel plated film 403 and the epoxy  
25 resin substrate 401 are separated from each other  
thereby to produce a stamper 404 as shown in Fig. 4F.  
The stamper 404 fabricated by this method has  
protrusions of the stepped pattern of the stamper 101

reproduced as it is from the original plate.

(Embodiment 3)

Still another embodiment of the invention will be explained below. This embodiment concerns a  
5 method of pattern transfer.

In the imprint technique, a pattern is transferred using a stamper through such steps that the substrate surface to which the pattern is to be transferred is formed with a resist film in advance,  
10 and the stamper is pressed against the resist film thereby to deform the resist. In this way, the stepped pattern formed on the surface of the stamper is transferred to the resist. In the case where the resist 502 formed on the surface of the object substrate 501 is  
15 not sufficiently deformed when the stamper 101 is pressed against the resist 502 as shown in Fig. 5, however, gaps 503 may be left with the stamper 101 resulting in a pattern defect.

A pattern transfer method for obviating this  
20 problem will be explained with reference to Figs. 6A to 6C. First, as shown in Fig. 6A, the surface of the stamper 101 having a stepped pattern is spin-coated with a resist 601 so that the resist 601 is filled in the recesses of the stamper 101. Next, as shown in  
25 Fig. 6B, the resist 601 is brought into contact with an object substrate 602, and then the resist 601 is hardened by heat treatment. The whole assembly is cooled to 25°C, after which the stamper 101 is

separated. In this way, the resist 601 is transferred to the surface of the object substrate 602, thereby producing the structure shown in Fig. 6C. According to this method, the stepped pattern can be transferred in the same manner as if the stamper is kept in contact with the resist coated in advance on the surface of the substrate, while at the same time suppressing the occurrence of a pattern defect which otherwise might be caused by an insufficient resist deformation.

10 (Embodiment 4)

Yet another embodiment of the invention will be explained below. In this embodiment, the surface of an object substrate is processed using a transferred pattern.

15 With reference to Figs. 7A to 7E, the process of steps for transferring a pattern will be explained. As shown in Fig. 7A, a glass substrate 701 with a resist 702 coated thereon is prepared. As shown in Fig. 7B, a stamper 101 is brought into contact with the resist 702 while at the same time heating the whole assembly to the glass transition temperature of the resist 702. In this way, the stepped pattern of the stamper 101 is transferred by the deformation of the resist 702. Next, the whole assembly is cooled to 20 25°C, after which the stamper 101 is removed. As shown in Fig. 7C, a resist pattern is obtained with exposed areas 703 on the surface of the glass substrate 701. The glass substrate 701 is processed using the exposed

areas 703. In the case where the thickness of the resist 702 is larger than the height of the protrusions of the stamper 101 in Fig. 7A, residual resist areas 704 are formed in the recesses of the resist 702 as  
5 shown in Fig. 7D. Therefore, the resist 702 is subjected to the reactive ion etching process (hereinafter referred to as RIE) having the anisotropic characteristic as shown in Fig. 7E, thereby making it possible to form a resist pattern having the same  
10 structure as in Fig 7C.

An explanation will be given of the steps of processing a groove having a complicated cross section in the surface of a glass substrate using the resist pattern obtained as described above. Figs. 8A to 8E  
15 are diagrams for explaining the steps of forming a groove in the surface of the glass substrate. Fig. 8A shows a state immediately after forming a resist pattern having an exposed area 703 of the glass substrate 701 by the pattern transfer process described  
20 above. By dry-etching the surface of the glass substrate 701 corresponding to the exposed area 703 with  $\text{CF}_4/\text{H}_2$  gas, only the part of the glass substrate 701 corresponding to the exposed area 703 is etched into the structure as shown in Fig. 8B. The subsequent  
25 resist etching by RIE until complete removal of the entire low-stepped portions of the resist 702 removes the resist and enlarges the exposed areas 703 as shown in Fig. 8C. Under this condition, the dry etching is

carried out with  $\text{CF}_4/\text{H}_2$  gas again. Only the exposed areas 703 are etched to form the structure shown in Fig. 8D. After that, the resist 702 is removed to produce a channel-shaped glass substrate as shown in  
5 Fig. 8E. In place of the  $\text{CF}_4/\text{H}_2$  gas used in this embodiment, such gases as  $\text{SF}_6$ ,  $\text{CF}_4$ ,  $\text{CHF}_3$ ,  $\text{CF}_4/\text{O}_2$ ,  $\text{HBr}$ ,  $\text{Cl}_2$  and  $\text{Cl}/\text{HBr}/\text{O}_2$  may be used with equal effect.

According to this embodiment, a plurality of resist patterns for forming a groove having a  
10 complicated shape of the cross section can be formed in a single pattern transfer process. Therefore, as compared with the conventional photolithography or imprint technique, the number of parts and the number of steps required can be reduced for a lower fabrication cost. Also, since the position matching between  
15 the patterns is eliminated, a shape having a high dimensional accuracy can be obtained easily.

(Embodiment 5)

A further embodiment of the invention will be  
20 explained below. This embodiment represents the steps for fabricating an optical waveguide using a pattern transferred.

First, as shown in Fig. 9A, a clad member 904 is formed on the surface of a glass epoxy substrate  
25 901, and held at  $150^\circ\text{C}$  for two hours thereby to thermally setting the clad member 904. The clad member 904 is made of a mixture of cycloaliphatic epoxy resin, methyl nadic anhydride and an imidazole-based catalyst.

After coating an ultraviolet-softened resist 702 on the surface of the clad member 904, the pattern is transferred using the stamper according to the invention.

In this way, a structure as shown in Fig. 9B is

5 obtained. Next, as shown in Fig. 9C, core members 902 are formed on the surface of the resist 702 and the exposed area 703, after which the core members 902 are thermally set by being held at 150°C for two hours.

The core members 902 are made of a mixture of liquefied  
10 bisphenol A-type epoxy resin, phenolic novolac resin and triphenyl phosphine as a material. The entire surface formed with the core members 902 is irradiated with the ultraviolet light by an ultraviolet lamp (not shown). Then, the ultraviolet light is radiated also  
15 on the resist 702 through the core members 902. In the process, as shown in Fig. 9D, the parts of the resist 702 located in contact with the core members 902 are exposed thereby to form softened resist portions 903.

The resist 702 is developed to remove the softened  
20 resist portions 903. At the same time, the core members 902 that have been formed on the surface of the softened resist portions 903 are removed thereby to produce the structure shown in Fig. 9E. Until the low-stepped portions of resist 702 are entirely removed,  
25 the resist etching is carried out by RIE. As shown in Fig. 9F, the portions of the resist 702 adjoining the core member 902 are removed thereby to form new exposed areas 703. As shown in Fig. 9G, clad members 904 are

formed on the surface of the resist 702, the exposed areas 703 and the core member 902, after which the clad members 904 are thermally set by being held at 150°C for two hours. Under this condition, the resist 702 is removed by the lift-off method or by development after radiating the ultraviolet light until the whole resist 702 is softened. In this way, as shown in Fig. 9H, an optical waveguide having such a structure that the core is surrounded by the clad member is obtained. Unlike in this embodiment using an epoxy material for the optical waveguide, such a material as polyimide, acryl or silicon may of course be used with equal effect. (Embodiment 6)

A still further embodiment of the invention will be explained below. This embodiment represents the process of steps for fabricating a multilayer wiring substrate using the pattern transferred.

Figs. 10A to 10L are diagrams for explaining the steps of fabricating a multilayer wiring substrate. First, as shown in Fig. 10A, a resist 702 is formed on the surface of a multilayer wiring substrate 1001 configured of a silicon oxide film 1002 and a copper wire 1003, after which a pattern is transferred by a stamper (not shown). The exposed areas 703 of the multilayer wiring substrate 1001 are dry-etched with  $\text{CF}_4/\text{H}_2$  gas. As shown in Fig. 10B, each exposed area 703 is processed into the shape of a channel in the surface of the multilayer wiring substrate 1001. The resist



702 is etched by RIE to remove the low-stepped portions of the resist 702. As shown in Fig. 10C, the exposed areas 703 are enlarged. Under this condition, the exposed areas 703 are dry-etched until the channels already formed reach the depth of the copper wire 1003. Thus, the structure shown in Fig. 10D is obtained. By removing the resist 702, the multilayer substrate 1001 having channel-shaped grooves in the surface thereof is obtained as shown in Fig. 10E. After forming a metal film by sputtering on the surface of the multilayer wiring substrate 1001 (not shown), a metal plated film 1004 is formed by electrolytic plating, as shown in Fig. 10F. After that, the metal plated film 1004 is polished until the silicon oxide film 1002 of the multilayer wiring substrate 1001 is exposed. As shown in Fig. 10G, the multilayer wiring substrate 1001 having a metal wiring in the surface thereof is obtained.

Another process of steps for fabricating a multilayer wiring substrate will be explained. The exposed areas 703 are dry-etched from the state shown in Fig. 10A until the copper wire 1003 in the multilayer wiring substrate 1001 is reached. The structure shown in Fig. 10H is produced. The resist 702 is etched by RIE to remove the low-stepped portions thereof to produce the structure shown in Fig. 10I. From this state, metal films 1005 are formed by sputtering on the surface of the multilayer wiring

substrate 1001 thereby to produce the structure shown in Fig. 10J. The resist 702 is removed by liftoff thereby to produce the structure shown in Fig. 10K. Then, the remaining portions of the metal films 1005  
5 are electrolytically plated thereby to obtain the multilayer wiring substrate 1001 having the structure shown in Fig. 10L.

As explained above with reference to the embodiments, the use of a stamper having at least two  
10 steps on the side wall surface of each protrusion of the stamper surface makes it possible to collectively transfer a pattern for forming a channel structure having a complicated shape of the cross section and a structure made of a plurality of materials. As  
15 compared with the conventional lithography and imprint technique, therefore, the fabrication cost can be reduced.

It will thus be understood from the foregoing description that according to this invention, a  
20 plurality of patterns can be collectively transferred so that the self-alignment can be achieved between the patterns, thereby making it possible to form a structure, a groove or a wiring having a high dimensional accuracy.

25 It should be further understood by those skilled in the art that although the foregoing description has been made on embodiments of the invention, the invention is not limited thereto and

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various changes and modifications may be made without departing from the spirit of the invention and the scope of the appended claims.